HIGHER AGRICULTURE GROWTH THROUGH TECHNOLOGY

I. Higher agriculture growth through technology

As Pakistan tries to embrace the third industrial revolution, the fourth has arrived! The advance of technology in the modern era is marked by four industrial revolutions[1]:

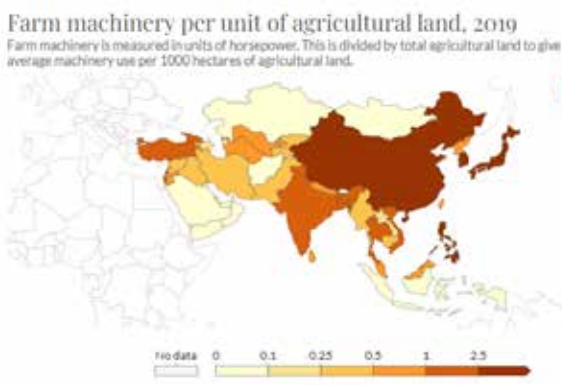
I. *The first industrial revolution* is placed in the late 18th century when the introduction of the steam engine and the harnessing of water power led to the mechanization of manufacturing;

II. *The second industrial revolution* is placed in the late 19th century to early 20th century when electricity catapulted mass production. In agriculture, these developments saw the global shift from manual work on farms through traditional tools and dependence on animal power to mechanical power on farms and mass-produced chemical inputs for farming. In Pakistan, this wave arrived in the form of the green revolution in the 1960s and 1970s which brought tractorization, mass-produced chemical fertilizers and agro-chemicals complemented by advancements in seed which led to new varieties and higher yields.

III. *The third industrial revolution* of the late 20th century rode on the development of electronics. This brought automated production using electronics, particularly programmable logic controllers, advanced IT systems, and robotics. From the early 1990s, this wave brought the development of precision agriculture through yield monitoring, guidance systems for farming, and variable rate application of agri-inputs on each portion of the farm based on its need.

IV. *The fourth industrial revolution* of the early 21st century is riding on big data, artificial intelligence, the Internet of Things, etc. This has begun to allow autonomous decision-making by cyber-physical machines using machine learning. In agriculture, this is beginning to allow autonomous farming using ubiquitous sensors.

Figure 4: Pakistan's agriculture: Yet to mechanize



Source: United States Department for Agriculture (USDA) Economic Research Service OurWorldInData.org/employment-in-agriculture • CC BY

Figure 4 uses a simple measure of mechanization to show that, while Pakistan has broadly embraced the second revolution, it is yet to fully embrace the third and fourth industrial revolutions. As a proxy for mechanization, figure 4 takes the estimated farm machinery in each country (measured in horsepower) divided by its total agricultural land.

1 Marco Brini (2023). *Digital Agriculture e-book.*

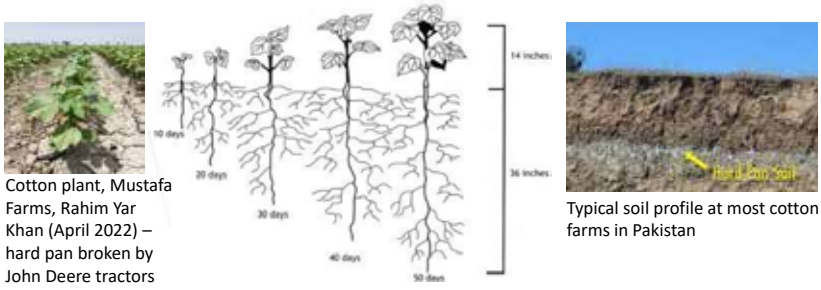
The features of Pakistan's agriculture sector today demand mechanization. The low yields per acre and small scale of farming operations lead to inefficient use of resources and higher unit costs. This means higher end-consumer prices despite low farmer profitability. The lack of modern drying, storage, and logistics infrastructure means higher post-harvest losses of commodity and the use of bags for grain storage and transport entails high labour costs. All this means higher costs for end-consumers. Finally, growers continue to lack the capacity to adopt better farming practices which are complemented by modern technology. **This chapter lays out how technology can be scaled up to bring higher growth to Pakistan's agriculture based on reduced inefficiencies and increased productivity.**

Traceable and sustainable cotton through two industrial revolutions

The rise in modern consumers' commitment to environmental sustainability and social standards has led to a shift in the global fashion industry. This has placed new demands on the global textile industry. Traceability and sustainability goals have increasingly become a requirement of global brands. Over fifty leading brands have signed the Textile Exchange's 2025 Sustainable Cotton Challenge to source 100 percent of their cotton from the most sustainable sources by 2025. Similar pledges have been made by other global brands. Therefore, Pakistan's textile industry is also beginning to look for traceability and sustainability in its cotton sourcing and processing. This is where a combination of technology from the third and fourth industrial revolutions can deliver.

In Pakistan a simple example modern technology enabling traceability and sustainability goals involves the practice of water delivery to cotton plants. A widespread issue across Pakistan's agriculture sector is the low power of Pakistan's locally-built tractors. This industry was given protection from imports some decades ago with the policy goal of indigenization of tractor production. Despite decades of this protection and direct government support to farmers for purchase of these tractors, Pakistan's most common tractors operate in the range of 50 horsepower. To put this in perspective, the Toyota Corolla Altis 1600cc model is marketed as capable of 120 horsepower at 6,000rpm (Indus Motors website 2023). The result of this low traction is that soil is typically ploughed to a maximum of about 18 inches by these tractors. This means that on most farms in Pakistan, soil compaction is usually found at 15- to 18-inch depth. This is called the 'hard pan' which must be broken for the cotton plant to grow sustainably.

Figure 5: Best to water the cotton plant through the soil



Cotton plant, Mustafa Farms, Rahim Yar Khan (April 2022) – hard pan broken by John Deere tractors

Typical soil profile at most cotton farms in Pakistan

As the middle panel in figure 5 shows, the cotton plant sets its root far deeper reaching over four feet and is best watered through its roots using the water retained by the soil it grows in. The photograph on the left shows the cotton plants at Mustafa Farms, Rahim Yar Khan, in April 2022 which were sown by Monosem pneumatic planters at consistent plant-to-plant and row-to-row distance to achieve higher plant population per acre. Before planting, the hard pan was broken down to four feet with John Deere tractors of up to 145 horsepower using a chisel plow. This means that the water retained by the soil is feeding the plants. That is why the surface gives a parched look but, despite this, the plant looks healthy. No surface water is being held which avoids a humid environment around the plants conducive for pests.

By contrast, the photograph on the right shows the hard pan (no cotton plant shown) which means that the roots of the typical cotton plant in Pakistan are found to turn at right angles at the depth of around 18 inches, sometimes even less. The natural need of the cotton plant is not being met because of inadequate farm machinery used season after season after season. This means that, instead of watering the cotton plant through the soil, excessive surface watering is commonly practiced in Pakistan. This provides a home to insects. This leads to a higher use of insecticides resulting in lack of compliance with global sustainability standards. Instead, if the correct farm machinery is used, less surface water will mean less insects, less insecticide sprays and greater sustainability.

The traceability and sustainability goals can be achieved on Pakistan's farms by combining multiple industrial revolutions: using appropriate machinery with accurate measurement through modern sensors using the Internet of Things. This can help Pakistan's processors in becoming more competitive in global markets. This is why Indus Dyeing, Mahmood Group, and Dynamic Sportswear have sponsored this project at Mustafa Farms in District Rahim Yar Khan with Farmonix as the machinery service provider and Mehrgarh Kasht as the project developer. A key question arises here: modern farm machinery is generally intended for a larger scale of cultivation—how can we get this machinery to the majority of Pakistan's smallholder farmers.

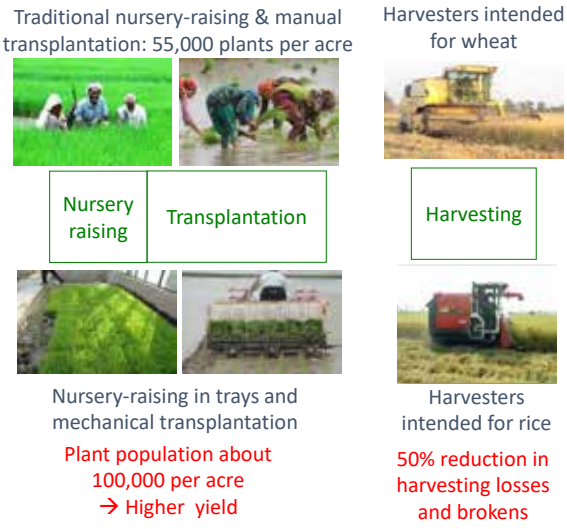
Service providers can deliver technology to Pakistan's farmers: The case of rice

The state of mechanization in Pakistan: In Pakistan, farm mechanization is taking place most commonly through informal service providers who import scrap machines from the Far East (China, Thailand, Vietnam, etc.). These machines have typically run their use life already and hardly any duty has to be paid for them. The import of the farm machines is generally through a registered company but the sales of these services to farmers are in cash and without any encumbrances of taxes paid to the government.

The skill of the machine operator makes or breaks the service delivered to farmers. And even in this landscape, there are expert machine operators who can also play the role of on-farm mechanics. This is important because the scrap machines meet frequent on-farm breakdowns while these services are being provided. The lack of parts inventory for these machines means delays in harvesting or sowing for farmers—these are parts of the cultivation cycle when time is literally money.

Globally, mechanization has been driven by the shortage of labour. The geographical regions where agriculture depends on wage labour (such as northern Punjab and lower Sindh) are already embracing mechanization of harvesting and, more gradually, mechanization of sowing. The shortage of labour during the harvest period is facilitating mechanization. For example, in northeastern Punjab's Kalar Tract—the Basmati region—rice harvesting has completely shifted to mechanical harvesters which has reduced the harvest period from 5-6 weeks down to a mere twenty days. This changes the commercial dynamics significantly for farmers preparing for the next crop as well as for traders. Similarly, lower Sindh faces serious shortages of labour particularly rice-growing areas around Karachi from which labour shifts to urban areas. Mechanization of the rice crop is also finding a home in this area. By contrast, upper Sindh and parts of southern Punjab where the sharecropping system dominates and labour is bound to the land, mechanization is not making much progress.

Figure 6: Shifting rice from manual to mechanical



The need to upgrade machinery-based service providers: The shortage of labour is only one key driver of mechanization. Advancing the example of the rice sector, whose exports have stagnated in the range of US$ 2-2.5 billion over the past decade, the modernization of harvesting and sowing is a need of both farmers and exporters to get higher yield from the same cultivated area. Pakistan's Basmati rice crop is now harvested mechanically but the harvesters used are old and mostly intended for wheat. According to a NARC study[2], yellow-colored New Holland combine harvesters seen across Pakistan during the harvest season led to rice grain losses of 5-19 percent while the scrap rice harvesters have grain losses of 2.2-5%. By comparison, a 2020 ADB study measured grain losses of new harvesters to be significantly lower: Thinker (1-2.5%), Kubota (0.8-3%). Grain breakage was also much lower for the new rice-only machines.

The adoption of imported hybrid seed in rice has increased yields but not to the level it can—mainly because sowing is not mechanized. Rice sowing is typically done in two stages: nursery-raising and transplantation. Since rice plants are highly vulnerable in the first 2 to 3 weeks after sowing, they are planted in a concentrated 'nursery' on half an acre to eventually cultivate fifty acres. After this initial period, the traditional method is to manually uproot these seedlings and transplant them all over the 50 acres. As figure 6 shows, this is back-breaking work done mostly by female labour while standing in the sweltering heat of June in about eight inches of standing water—the traditional practice of flood irrigation. An increase in Pakistan's rice exports clearly requires a shift from traditional nursery raising and manual transplantation of seedlings to nursery-raising in trays which allows transplantation by machines.

2 National Agricultural Research Center (2017). Factors causing low head rice recovery in combine-harvested paddy, Tanveer Ahmed, Zulfiqar Ali, and Hafiz Sultan Mahmood. https://inis.iaea.org/search/search.aspx?orig_q=RN:50046429

Traditionally, government policy focused on machine ownership by individual farmers. But machine ownership requires scale. A rice transplanter achieves eight acres a day and 88% of Pakistan's farms are less than 12.5 acres. Modern machines are complex and require daily maintenance which means that properly trained operators are essential. For applications such as transplantation, the interaction between machines and the soil and conditions in each agro-climatic zone need to be understood for achieving results. This requires trained agronomists and entomologists. Finally, an inventory of frequently atrophied parts is needed to rapidly address on-farm breakdowns. All this needs capital and scale. This is why existing informal service providers need help to upgrade; new service providers are required in the formal sector.

The trajectory of rice mechanization in Vietnam in the past two decades[3]. At the turn of the 21st century, Vietnam's farmers were using imported second-hand combined harvesters from Japan, China and Thailand, as Pakistan's farmers are doing today. During the first decade of this century, some 15 Vietnamese companies were competing to produce their own designs. In parallel, small service providers were importing cheap Chinese machines and offering services to farmers. By the end of the decade, with vigorous incentivization of rice exports by the government, a massive rise in rented machinery services took place both among large farmer and small farmers while ownership of machines by farmers stagnated at a low level. With the shift towards quality machines for service provision, the Japanese brands Kubota and Yanmar had 95 percent of market share by 2015 with only 2 local brands operating. With the expansion of the market for new machines, Kubota has started manufacturing combine harvesters in Vietnam. The availability of appropriate technology for small farmers has allowed them to stay competitive as farm wages rose. Vietnam's small farmers also 'aggregated' their farm holdings under the 'small farm, large field' model to gain scale. The Government of Vietnam also required rice exporters to purchase 10 percent of their rice paddy directly from farmers rather than middlemen. This incentivized rice exporters to support the upgrade of farmers' cultivation methods.

The need for modern service providers has been understood by leading rice exporters of Pakistan. Investment has been made in farm mechanization by companies like Jaffer Brothers, Meskay & Femtee Trading, Garibsons, MM Commodities, Conwill Pakistan, RBI, etc. In parallel, global rice machinery brands have also appointed agencies in Pakistan: Kubota of Japan, Fuerdai of China, TYM of South Korea, etc. But mechanization demands scale. As done in Vietnam, Pakistan needs to transition towards local manufacturing of modern farm machinery. This will require building a national fleet of new machines that justifies machine manufacturing in Pakistan. Government and donor institutions must support large-scale training of farmers, machine operators, helpers, mechanics, and agronomist to populate this eco-system. The import of machines older than a certain number of years must be gradually phased out. The service providers in the informal sector must be facilitated to upgrade their machinery fleets as well as staff expertise to be able to provide better services to farmers.

3 IFPRI (2018). *Evolution of Agricultural Mechanization in Vietnam.*

Building the backbone for Pakistan's fragmented fruit and vegetable value chains

Figure 7: A good crop can die at the mandi

The fragmented structure of Pakistan's fruit and vegetable value chains destroys value from end to end. At the production level, small holder farmers dominate with limited scientific and technical knowledge of their crops. More importantly, they have low awareness of the requirements of export markets. The wholesale markets are also fragmented with intermediaries taking a short-term 'trader mindset'. This part of the chain has opportunistic players with few long-term relationships. There is hardly any investment in quality at these markets and little value addition associated with them. Next, there are a limited number of processors—with few direct links with farmers—with some export. Ninety percent of Pakistan's fruit and vegetable output is consumed domestically. The links between wholesale markets and end-consumers are mostly small, traditional retailers with informal quality standards. The produce that is exported is typically through fragmented, small exporters who deliver mixed quality and mixed branding for Pakistan as a source. The lack of cool chain infrastructure causes post-harvest losses of 2 to 4 times higher than good practice in other countries.

The main constraint to realizing the growth potential of this sub-sector is the broken link between growers and export markets. This vicious cycle of low investment, low productivity, and low profits results in poor branding: Pakistani produce fetches lower prices in export markets than comparator countries. Therefore, yields are often forty percent lower than comparator countries. At the core of this under-performance is weak demand pull for quality produce in larger quantities. If there is one element that can completely change the landscape for these perishable commodities, it is investment in cool chain infrastructure. But, as in other cases presented in this paper, the introduction of technology requires a different commercial arrangement which aligns the incentives for investment in technology. Growers also clearly articulate their need for an off-take guarantee to start making on-farm investments.

The commercial driver for this development is guarantee off-take of not only the fruit and vegetables but also of the cool chain infrastructure's services. No serious investment in an entire cool chain can be justified without a significant off-take commitment to ensure adequate capacity utilization. And since only a small portion of Pakistan's local markets and end-consumers for fruits and vegetables value quality and pay extra for it, an off-take commitment linked to the global export markets is what will fit the bill.

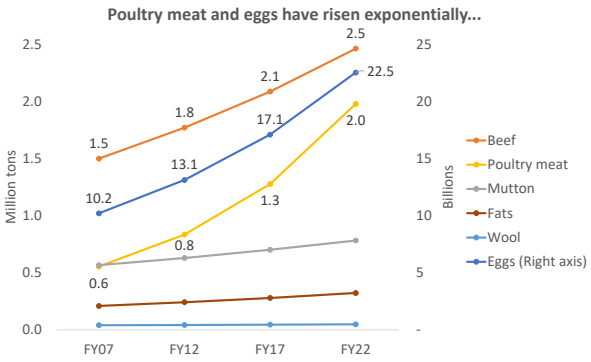
Global players are needed to upgrade Pakistan's fruit and vegetable value chains. Food majors need to be attracted to Pakistan under an arrangement of off-take guarantees for global export markets to justify the investments in cool chain infrastructure. The same off-take guarantees can be extended back-to-back to farmers to incentivize their on-farm investments and delivery of produce. Many larger farmers express interest in developing collection points on their premises by hosting pack houses, but only if the requisite off-take guarantee and some capacity building can be offered.

Pakistan's poultry sector is a success story of growth through technology

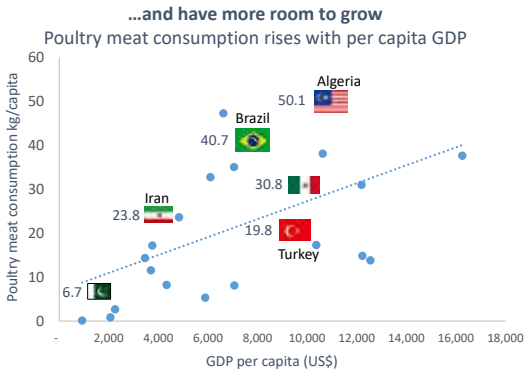
Pakistan is the 11th largest producer of poultry in the world with 1.7 million poultry birds which have quadrupled in the past 15 years. In 2022, the output of these birds was 22.5 billion eggs and about 2 million tons of poultry meat. This poultry farming sector is globally competitive on quality. State-of-the-art facilities are installed at some 70 percent of the parent stock farms and about 60 percent of broiler farms (see Annex A for explanation).

The rise of poultry in Pakistan is founded on the introduction of technologies right along the value chain. This made continued growth possible. Two technologies stand out: controlled sheds introduced in the mid-1980s (see Annex A) and hybrid maize seed introduced in 2001. Controlled sheds were a game-changer because the poultry feed conversion (or feed-to-meat) ratio deteriorates if temperatures are outside the recommended comfort zone for chickens. Controlled sheds provide the optimum environment to obtain better feed conversion ratio, uniform air movement, lower medication cost, and lower bird mortality. All are critical for the profitability of poultry farming.

Figure 8: The past and (possible) future of Pakistan's poultry sector



Source: Economic Survey of Pakistan 2022



Source: OECD 2022

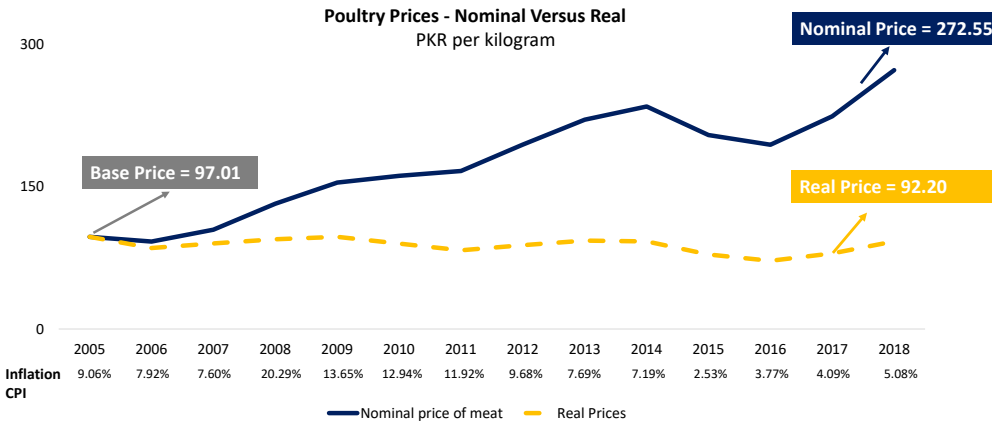
Poultry feed is a significant component of the cost of poultry farming. Modern poultry feed typically comprises some forty five percent maize, twenty percent soybean meal, and the rest is agriculture and livestock residue and by-products. The rising adoption of hybrid maize seed since 2001 has led to a tripling of maize yields from 18 maunds per acre nationally to 60 maunds per acre according to the Economic Survey of Pakistan (mechanization of maize cultivation can increase it further). And, as farmers

continued to switch to maize, the area under this crop has also continued to increase. Maize farmer's profitability has risen with this. Today, more than 70% of the maize grown in Pakistan goes towards poultry feed mills. Import of soybean (which began in 1984) has also improved the feed mix given to poultry which has improved the productivity of the sector. This sector is the largest consumer of agriculture and livestock residue and by-products: oilseed meal, wheat bran, rice polish, broken rice, etc. In 2018-19, residues made up ten million tons of poultry feed. So, the rise of poultry has also lifted other sectors with it.

A thriving poultry value chain can convert imported grandparents into exportable processed poultry products. Import of chicken with high genetic potential has made this growth possible. Some 95 percent of Pakistan's poultry is now grown on commercial farms. These birds have the genetics that can respond to this modern nutrition. The traditional 'desi' chickens would not gain weight from the same nutrition since they do not have the suitable gene pool for it. The scale-up of poultry production through technology has actually allowed the price of poultry meat to fall in real terms, i.e., after eliminating the rise due to general inflation (figure 9). This is the way to identify the change in prices due to factors internal to the poultry sector rather than changes in the general level of prices.

The success story of poultry bears lessons for growth in the wider agriculture sector. First, for sustained growth, technology additions have to be facilitated right along the value chain, not just in one link of the chain. Second, import of genetic material is critical for high productivity. And, equally important, scale-up in production levels can make the end-product more affordable for the public.

Figure 9: With technology, the real price of poultry has fallen



Source: World Bank, IndexMundi

Welcoming the fourth industrial revolution

In recent years, a number of start-ups have begun to develop agri-tech solutions to solve problems in Pakistan's agriculture sector. A few broad categories of 21st century agri-tech are arriving in Pakistan. One category operates in digital financial services. An example is Ricult: a company which uses agronomy and profile data to assess farmer affordability for financial services. The data helps develop financial products that fit farming cycles better and provide improved risk management for banks and institutions with better financial access for farmers. Another category is focused on aggregating inputs and outputs. For example, Jiye Technologies operates a platform that provides farm inputs, yield enhancement advisory, information on market prices, farming contracts, and trade agreements to farmers and also helps link the farmers to retailers. A third category aims to bring efficiency in 'last mile' deliveries between the 'mandi' and the end-consumer. The most celebrated among these is Tazah Technologies which started in late 2021 to bring efficiency in the last mile of horticulture value chains. However, they subsequently pivoted to trading of grains under their brand Tazah Global. Another focus is precision agriculture: Sapphire is offering drone-based spraying solutions. It is often argued that agri-tech ideally performs in tandem with the technologies of the third industrial revolution, not just the second industrial revolution. The jury is still out on this.

Conclusions and policy priorities

For growth in agriculture through technology, the most important conclusion is that a shift in the technology of production is ideally driven by the demand side. In Pakistan, the demand for greater environmental and social sustainability with fully traceable sourcing of cotton is becoming a driver for leading textile players to invest in mechanized cotton cultivation. Rising demand in global rice markets has driven leading rice exporters to bring hybrid rice seed to Pakistan and invest in farm machinery service providers. The ability of such investments in technology to bring scale, reduce cost, make agri-commodities more affordable for the public, and make exports competitive has been demonstrated amply by Pakistan's poultry industry. But introduction of technology usually requires new commercial relations.

Processors who have invested deeply in 'backward integration' to form deeper connections with farmers through contract farming have already set good examples: Rafhan in maize, JDW in sugarcane, Nestle in milk, etc. But scaling up the adoption of technology across Pakistan's small-to-medium-sized farms requires another type of entity: the farm machinery service provider. Service providers large and small, formal and informal, must be supported actively to upgrade cultivation at both large and small farms. Service providers are the entities which can facilitate farmers' shift to cultivation practices that complement mechanization. A shift from scrap machines to a national fleet of new machines is needed to move Pakistan towards local manufacturing of globally competitive farm machinery. Training is a must.

For sustained growth, technology additions need to be facilitated right along the value chain. The poultry sector's growth bears the examples of controlled sheds introduced in the mid-1980s and hybrid maize seed introduced in 2001. Invariably, the continuous introduction of better genetic material, whether in the form of seed for crops or grandparent stock for poultry, is the fulcrum of growth in productivity.

Some segments of the agriculture sector (such as the fruit & vegetables supply chains) require the introduction of global players that can ensure guaranteed off-take for global export markets. This assured market makes larger investments in cool chain infrastructure and on-farm technologies more feasible.

Overall, the 'pull factor' from processors and the existence of service providers may not translate into a nation-wide wave. The international experience indicates that the cost of agricultural labour is a more important determinant of the demand for mechanization than cost of capital.[4] The movement of labour to industry typically drives labour shortages in rural areas which create the need for mechanization. This is already visible in large parts of Pakistan's agriculture landscape. But complementing this trend, a transformation of the agriculture sector is required from supply chains dominated by government decisions and 'permanent winners' towards more competition and market-based commercial relations.

The international experience shows that in countries where agricultural wages are low and the reform is not taking place (in markets for farm inputs on one end and agri-commodities on the other), policies to increase farm mechanization based on subsidized finance to reduce the cost of capital are likely to have limited impact on agricultural growth. Mechanization alone cannot solve the broader problems of agriculture such as lack of reform in inputs and agri-commodity markets, weak financial systems, and poor business environments. A broader will to infuse competition and higher growth is critical for catapulting agriculture to the next level. Long-standing protections to key domestic industries like tractors must go!

4 The World Bank (2010). F*arm Mechanization: A New Challenge for Agriculture in Low and Middle Income Countries of Europe and Central Asia,* World Bank Working Paper No. 53318-SAS, page 59.